LIGHTNING
A BOLT FROM THE BLUE

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Universiti Putra Malaysia Press
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Selangor Darul Ehsan

Tel: 03-89468851/89468854
Fax: 03-89416172
Email: penerbit@putra.upm.edu.my
Website: www.penerbit.upm.edu.my

ISBN: 9789673446803
9 789673 446803

INAUGURAL LECTURE series

Profesor Ir. Dr. Mohd Zainal Abidin Ab. Kadir

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PROFESOR IR. DR. MOHD ZAINAL ABIDIN AB. KADIR

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17 FEBRUARY 2017

Auditorium Jurutera
Fakulti Kejuruteraan
Universiti Putra Malaysia

Universiti Putra Malaysia Press
Serdang • 2017
http://www.penerbit.upm.edu.my

Cetakan Pertama 2017

Penerbit UPM adalah anggota Persatuan Penerbit Buku Malaysia (MABOPA)
No. Ahli: 9802

ISBN 978-967-344-680-3

Reka letak teks : Sahariah Abdol Rahim @ Ibrahim
Reka bentuk kulit : Md Fairus Ahmad

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Mohd Zainal Abidin Ab. Kadir

ABSTRACT

To the electric utility engineer, the parameters of the flash that are of primary interest are the crest current for the first and subsequent strokes, the waveshape of these currents, correlation between the parameters, the number of strokes per flash and flash incidence rates where the ground flash density is denoted as flashes per square km-year and symbolised by N_g. The first three parameters, as we know them today, are to a very large extent based on the measurements of Berger. Berger's masts, 70 and 80 metres high, were mounted atop Mt. San Salvatore (Switzerland), which is 650 metres above Lake Lugano, where it can be readily noted that these 125 records represent one of the best and most extensive sets of data available to the industry to date. This inaugural talk focuses on the lightning severity scenario in Malaysia, which could also be applicable to other tropical countries, and some of the useful parameters for lightning protection system design and forensic study. Some specific engineering applications and solutions are summarised, taking into account various lightning parameters, available from past and current measurements. These include the first national circular on lightning protection system installation for buildings, lightning protection guide on building and recently released guidebook on lightning protection for photovoltaic (PV) systems published by the Energy Commission of Malaysia and Sustainable Energy Development Authority (SEDA), respectively.

> *It is He who shows you lightning, [causing] fear and aspiration, and generates the heavy clouds. And the thunder exalts [Allah] with praise of Him - and the angels [as well] from fear of Him - and He sends thunderbolts and strikes therewith whom He wills while they dispute about Allah; and He is severe in assault.*
>
> [Ar-Ra'ad: 12-13]

INTRODUCTION

Lightning is one of the most fantastic natural phenomena in the world. It can result in severe damage to property. Lightning happens when a region of atmosphere acquires a sufficiently large electric charge that is capable of causing an electrical breakdown. It has been reported that there are 2000 thunderstorms in progress at any time resulting in 100 lightning flashes to ground per second; this is 8 million per day. It causes around 100 deaths and 250 injuries in the United States per year, more than from any other weather-related phenomenon. Even though there is no such database regarding the victims or survivors due to the lightning, but some cases have been well documented especially with related to the injuries and the deaths caused by the lightning. It has become a significant threat to many countries where the natural phenomenon has previously been treated only as an occasional attacker of careless living beings. Most tropical countries, several southern states of the U.S.A., Japan, and several parts of Australia, experience heavy annual lightning occurrence density.

It is a fact that Malaysia encounters more than 70% of power outages due to lightning and it is known as the "Crown of Lightning" in the world. The effects of lightning on electrical/communication networks and structures account for equipment damage, downtime/ data losses and malfunctioning of control and automated systems that may cost the nation over millions of ringgit and thousands of human injuries and deaths.

Malaysia has been ranked among the top three in the world in terms of the lightning density, more than any other countries in Asia. The lives of these people could have been saved if they were given proper education in lightning protection. Apart from human injuries and deaths, another matter of concern is the innumerable deaths of animals caused by lightning every year.

This inaugural lecture briefly presents the overview of lightning scenario in Malaysia and its impact towards the safety and energy security. Some parameters of interests for engineering application, will also be discussed, based on previous CIGRE documents on the subject published in ELECTRA more than four decades ago by Berger *et al*. (1975) and Anderson and Eriksson (1980). Measured lightning generated electric field with its unique characteristic will briefly be explained, apart from a sample of case study carried out, taking into account the usefulness of some lightning parameters, obtained from lightning location system. Last but not least, current progress with regards to the solutions in the forms of standard and policy development will also be highlighted for the benefit of the readers and audiences.

LIGHTNING GENERATED ELECTRIC FIELD IN MALAYSIA AND ITS DISTINCTIVE FEATURES

Since early 1930s, the breakdown process in the cloud discharged has been studied in a structured fashion in order to understand the lightning initiation mechanism. There is another method for considering on lightning effects to visually observe the discharged process of the cloud, some valuable information of the initiation of the process could be provided by the electric field remote sensor.

Based on previous studies, it was found that large microsecond scale pulses were typically being observed at the beginning of the cloud discharged that could be related to the breakdown process initiation.

Over the years, various researchers have done reliable works to measure and model various features and effects of lightning discharge with varied success.

These works served to improve our understanding of the physical meaning of the lightning processes and the role of lightning in the global circuit.

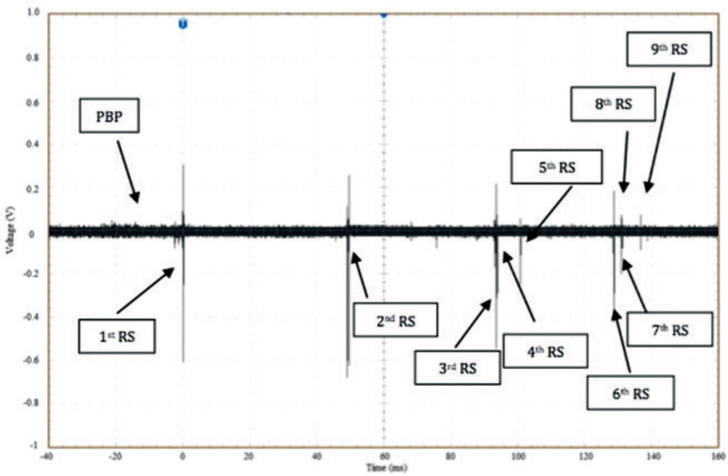
Measurement of the electric field was recoded on November 2013 at Universiti Putra Malaysia (UPM) (2°59’19.9”N 101°43’29.8”E) in Serdang Selangor area during monsoon period. Selangor has a tropical rainforest climate with monsoon rain from November to February blowing to Strait of Malacca. From a total of 172 lightning ground flash records were analysed, out of which 57 flashes contained positive lightning with a number of them having high number of subsequent return strokes which is somewhat unusual with the observations in other locations contrary to the majority of positive lightning return strokes that have been recorded previously, where the average multiplicity, M_{AVG}, is one, this study showed a high average multiplicity of which is almost four times higher than that is usually observed. Table 1 generalises the studies that have been experimented on positive lightning in the past for their respective number of strokes and average multiplicity, M_{AVG}. This is one of the examples on the interest of positive lightning, which intends to highlight the distinctive features of these measured electric fields.

Table 1 Occurrence of Positive Return Strokes in Flashes and MAVG of Numerous Studies

Study	Number of Flashes	Percentage of Different Number of Strokes in Flashes					Average Multiplicity
		One Stroke	Two Strokes	Three Strokes	Four Strokes	More than 4-Strokes	
Qie *et al*. [29]	185	175 (94.59%)	9 (4.86%)	1 (0.55%)	0	0	1.06
Nag and Rakov [30]	52	42 (81%)	9 (17%)	1 (2%)	0	0	1.2
Saba *et al*. [31]	103	83 (80%)	19 (18%)	1 (2%)	0	0	1.2
Fleenor *et al*. [32]	204	195 (96%)	9 (4%)	0	0	0	1.04
Heidler and Hopf [33]	44	33 (75%)	8 (18%)	2 (5%)	1 (2%)	0	1.34
Our study	57	9 (15.79%)	14 (24.56%)	10 (17.54%)	9 (15.79%)	15 (26.32%)	3.86

Figure 1 shows one of recorded flashes that occurred at 15:22:54 on 31/10/13. Nine positive RSs were found to be presence in the flash with a small intensity PBPs preceding the first positive return stroke.

Figure 1 The Electric Field Return Stroke Waveform of Flash with a Timeframe of 20 ms



TOWER INITIATED LIGHTNING DISCHARGES

The behaviour of a lightning current traversing along a tall structure is influenced by the factor of the ground reflection coefficient parameter. This parameter is widely assumed to be constant in the analysis of lightning current along a tall structure. However, in reality, the ground reflection depends on the relationship between the tower and ground impedances which results in multiple values for the ground reflection coefficient. These values are determined by the ground impedance, whereby the grounding electrode arrangement and soil resistivity play key roles.

A tall structure with a height of more than about 100 m is in danger of possible frequent exposure to strikes by lightning. When such an incident occurs, basically, the lightning current will travel down across the body of a tall structure and pass through the grounding system. It should be noted here that the mechanism of reflection at the top and bottom of a tall structure has a significant effect on the lightning current across the structure [34–36]. Thus, combined knowledge of the lightning current across the tall structure and an effective grounding system may result in understanding the multiple lightning current wave shapes along the body of the tall structure with respect to the reflection factor. This result may be of benefit to the tall structure which most likely would have sensitive equipment installed along the body of the structure, for example, a telecommunication (TM) tower. TM towers have equipment installed along the tower, and therefore frequent lightning incidents may lead to the malfunctioning of this equipment and associated systems which result in poor information transfers for the users. Thus, the protection of equipment along TM towers is very important where the current wave shape at different heights should be determined based on the current behaviour along the tower. This is a requirement in order to set the appropriate protection level for the systems.

The behaviour of a lightning current along a tall structure is influenced by elements of the height structure and reflection coefficient. The lightning current will travel along the tall structure towards the tower base and the difference between the two impedances, namely the tower surge impedance and the ground impedance, causes the reflections propagate back up the tower. This ground impedance is also known as the ground reflection factor (GRF). Subsequently, this current will travel upward after reflection, and again, will be reflected at the top of the tall structure. This is known as the top reflection factor (TRF). The reflections arise because of the difference between the tower and channel impedance. Hence, this situation may lead to an additional amplitude current along the tall structure and contribute to the different wave shape of the lightning current. However, this situation has not particularly attracted the attention of researchers. It is generally assumed that the reflection factor is a constant value and is widely considered as such in the analysis of the behaviour of current along a tall structure and the lightning channel.

Past research has shown that the lightning current along a tall structure is dependent on the ground reflection factor. Most of the previous researchers assume this factor to be a constant value. However, the ground reflection factor represents the correlation between the ground and tower impedances which is usually ignored by researchers. The ground impedance has a direct relation with the different types of grounding system as well as the different values of the soil resistivity which together generate multiple values. Hence, a relationship between the ground and tower impedance can give rise to multiple values of the ground reflection factor which may affect the lightning current along a tall structure.

Furthermore, it is noted that the GRF has a relationship between the ground and tower impedance whereby the ground impedance (or ground resistance) plays an important role in this study. The ground resistance can be determined through the relationship of the grounding system, ground electrodes, the arrangement of the grounding system and the variation in the soil resistivity value. Such relationships justify the notion of the non-validity of considering the GRF as a constant. Therefore, the constant value considered in the literature for GRF may have seriously affected the computational results for the lightning current profile along tall structures.

It is well understood that the higher the structure height, the higher the chances of getting struck by the lightning, although that is not always going to be the case. Taking into account the mechanism of reflections which has been discussed earlier, the voltage that builds up at any point of interest can cause damages to the electrical equipment installed along the tall structure. Figure 2 illustrates this incident in details. When a lightning strikes a tall structure, the injected lightning current propagates in two directions, one propagates upward through the lightning channel with certain return stroke velocity and the other one propagates down the tall structure itself at the speed of light (due to the shorter distance as compared to the former). As the lightning current propagating down the tall structure and meet the ground surface, there will be reflections up and down the tower due to the impedance differences between the tower and ground surface, whereby this event is dependent on GRF value which influences the reflected current whereby a constant value of GRF influences much of the reflected current.

Correlation between the impedances of a tall structure and ground plays a big role in determining multiple values of GRF. By keeping the tall structure impedance constant to a value of 150Ω, the ground impedance can be varied depending on the grounding system arrangement as well as the soil resistivity values. Hence, the reflected current along the tall structure will be determined based on the GRF, where the grounding system arrangement and soil resistivity effect are taken into account. Therefore, the outcome of this study is very much significant towards an understanding on this phenomena and its possible damages to the assets which are installed at any location at the tower. The evaluated current at any point of interest along the tower provides an important indication to the engineers to take into consideration on the type of grounding system to be chosen as well as the soil resistivity value which needs to be accounted for. However, this effect has seldom been investigated and considered by researchers due to the complexity of the calculation and numerical technique to be used.

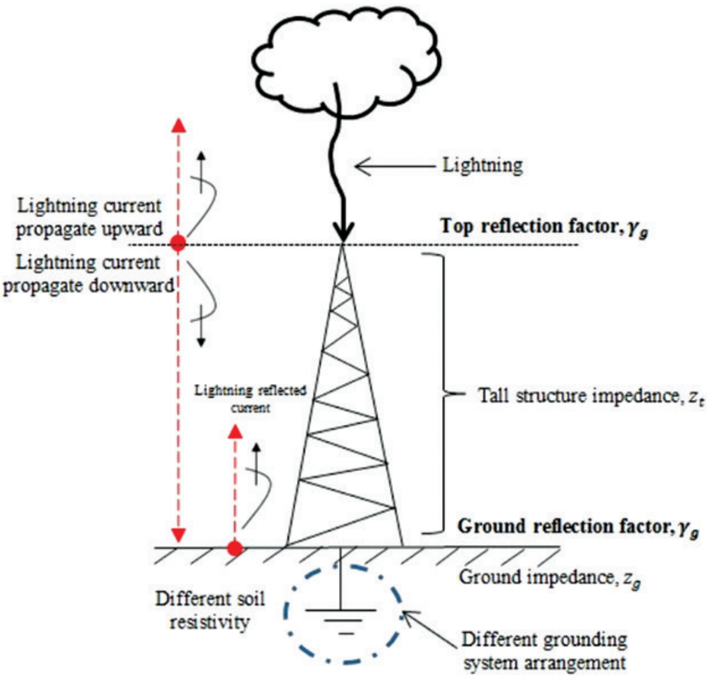


Figure 2 Illustration of Lightning Strikes to a Tall Structure

IMPACT OF LIGHTNING

Safety

Many cases lightning fatalities and injuries involved outdoor activities such as fishing, agriculture, recreation and sheltering in an unsafe or unsuitable place. Another issue is related to the economic impact to workers in some areas of South East Asia such as Malaysia, Thailand and Indonesia, where the planting and harvesting periods of the crops happen during the monsoon periods. Experts use the estimate that lightning is fatal in about 1 in 10 lightning- strike victims, although it is unknown if the death-to-injury ratio is similar in all countries. Table 2 shows the fatalities and injuries based on the number of victims, which were recorded since 2008 until May 2016. There is no indication at all that the lightning fatalities and injuries have decreased over the years and therefore much effort are needed to educate and create awareness among the public.

Table 2 Lightning Fatalities and Injuries Recorded in Malaysia from 2008 – 2016 (As of May 2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	3	0	0	3	3	2	0	0	0	0	9	0	20
2009	0	0	0	0	13	6	0	0	0	8	0	5	32
2010	0	0	0	2	0	0	0	0	9	2	0	0	13
2011	1	2	1	0	0	3	3	12	2	1	4	1	30
2012	0	5	1	56	7	1	5	5	1	0	5	0	86
2013	0	12	1	2	0	0	2	1	2	0	0	0	20
2014	0	0	4	1	2	0	0	0	0	2	2	0	11
2015	0	0	0	12	4	0	1	1	5	0	0	0	23
2016	2	0	1	2	6	0	0	0	0	0	0	0	11
Total	6	19	8	78	35	12	11	19	19	13	20	6	246

Another study was conducted by Hajikhani *et al.* (2016) to evaluate the casualty and injury risks associated with lightning in Malaysia. Locations and activity were categorised into six classes namely indoors, outdoors, agriculture, sports, recreation and small structures. The outcomes of the study, from various perspectives, are depicted in Figures 3 to 7.

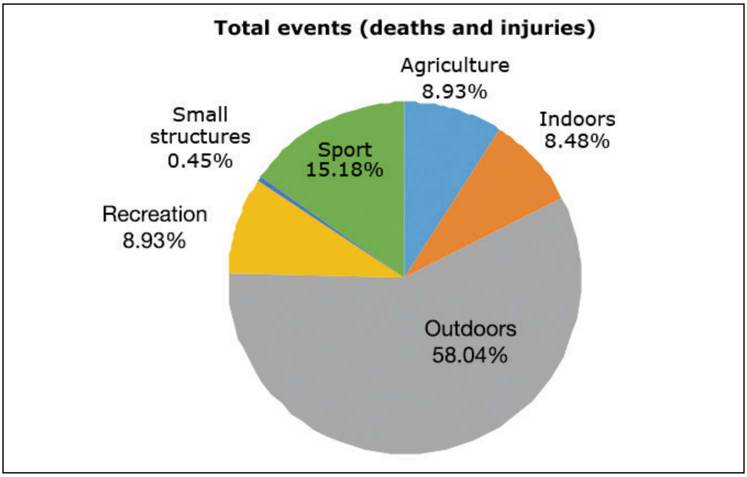


Figure 3 Total Deaths and Injuries Associated with Locations and Activities

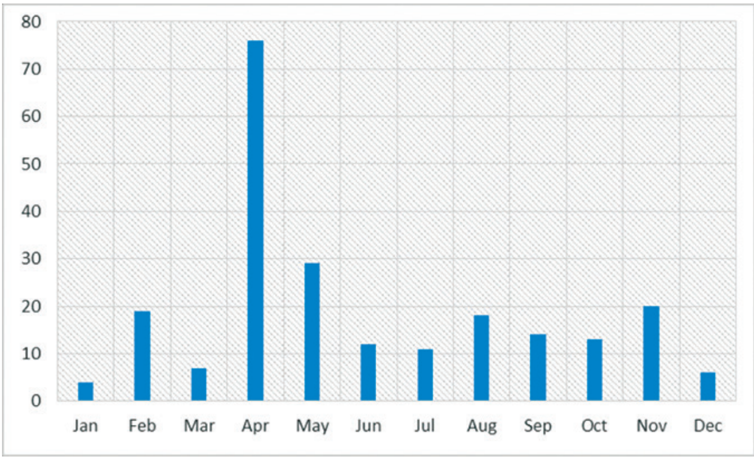


Figure 4 Distribution of Lightning Injuries and Deaths Based on Month (2008-2015) (n=224)

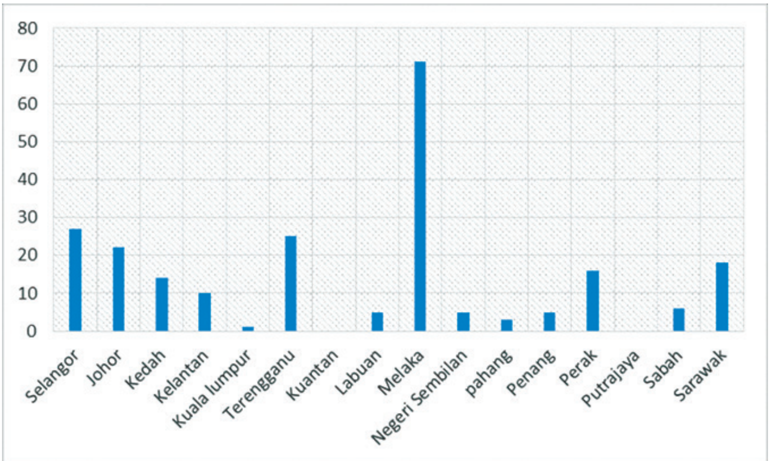


Figure 5 Distribution of Lightning Fatalities Based on States and Month from 2008 to 2015

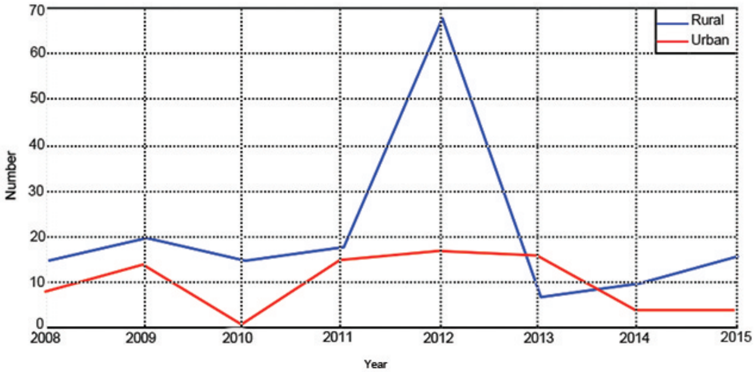


Figure 6 Distribution of Lightning Fatalities in Rural and Urban Areas (2008-2015)

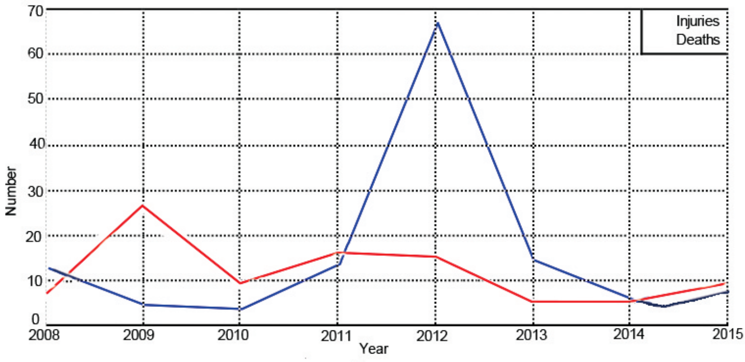


Figure 7 Distribution of Lightning Injuries and Deaths in Malaysia (2008- 2015)

ENERGY SECURITY

Electric utilities experienced high number of line outages due to lightning as reported by various authors. In Southern China for example, statistics shows about 70% of line outages are due to lightning while in Brazil, CEMIG declared 67% of transmission line outages are due to the same root cause. In Indonesia, 66% of 150 kV line outages were reported due to lightning. Similarly in Australia, Gillespie and Stapleton reported that 40.5% of the cause of outages at their 275 kV network in 2004 were due to lightning.

In evaluating overhead lines performance, there are list of available standards such as IEEE Std. 1410 and IEEE Std. 1243 that can be used. However, it is always a challenge for users from the tropical countries as these standards and procedures are generally designed to be used in non-tropical countries such as United States of America, Canada and European region. Recently published work by CIGRE WG C4.410 for example shows calculation on high voltage line performance with 4.7 and 4.9 flash per km^2 per year stroke density which are somewhat not comparable with the GFD value in tropical countries which are typically 30 to 40 flashes per km^2 per year and this was found to be the biggest concern in lightning protection system design. Lightning outage rate was reported by several authors (See Table 3).

Table 3 Recorded and Reported Transmission Lines Performance in Electric Utilities

No	Utility or Line Name	Country	Estimated Footing Resistance (Ω)	No. of Earth Wires	Line Voltage (kV)	Outage Rate (per 100km/yr)
Tropical countries						
1	CEMIG	Brazil			34.5	62
2	CEMIG	Brazil			69	40
3	CEMIG	Brazil			138	30.33
4	Angostura-B	Mexico	15	2	115	14.55
5	KKRI-GMSG	Malaysia	10	2	132	4.26
6	ATWR-BTRK	Malaysia	5	2	500	0.51
Non-tropical countries						
1	Ontario-Hydro	Canada	200	1	115	5.72
2	NEA	Australia	10	1	132	1.86
3	ECNSW	Australia			132	4.47
4	Com. Edison	USA			138	4.97
5	Tokyo	Japan			140	2.24
6	TVA	USA	30	2	161	1.99
7	Seq. to Charleston	USA			161	3.83
8	S. Jackson to Cordova	USA			161	0.55
9	SECV	Australia	28	1	220	1.02
10	CIGRE line #30				230	0.24

11	Tokyo	Japan			250	1.12
12	ECNSW	Australia			330	0.93
13	OVEC	USA	5	1	345	4.72
14	CIGRE line #31				345	3.44
15	Johns to Cordova	USA			500	0.3
16	Brown F. to West P.	USA			500	0.94
17	CSPG	China		2	500	0.74
18	Powerlink	Australia	10 - 20		132	3.3
19	Powerlink	Australia	10 - 20		275	0.3 – 0.7
20	Powerlink	Australia	10 - 20		330	0.3 – 0.7

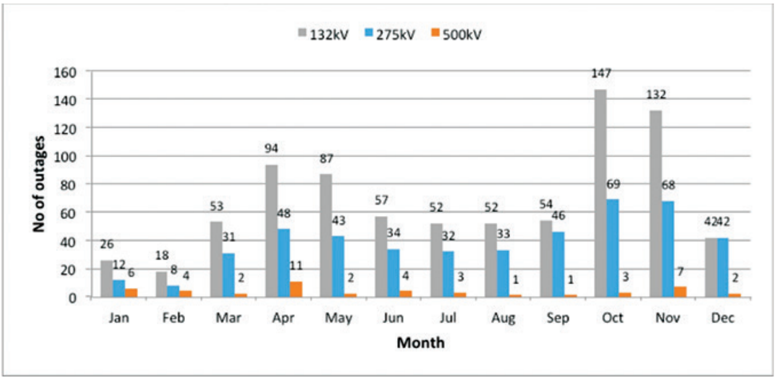


Figure 8 Transmission line outages due to lightning in peninsular Malaysia (from 2002 – 2015)

In Peninsular Malaysia, transmission line consists of 132 kV, 275 kV and 500 kV systems. From 2002 until 2015, total number of outages were recorded and compared to the lightning activity throughout the year. Figure 8 shows a double- peak pattern on the total number of line outages in peninsular Malaysia for 132 and 275 kV lines. Outages due to lightning were found to be higher in the month of April to May and October to November. This pattern was observed in the annual lightning activities, which are also higher during the monsoon interchange season, which is in April to May and October to November. Similar pattern was however not observed for 500 kV lines due to the fact that they were designed with higher insulation level in order to withstand higher lightning current. Some of the lines were energised at lower voltage level i.e. 275 kV.

Figure 9 presents different sources of damage to electronic devices. It is possible to distinguish that the greater sector of the total damages is mainly caused by surge overvoltages, which part of them are generated due to lightning discharges.

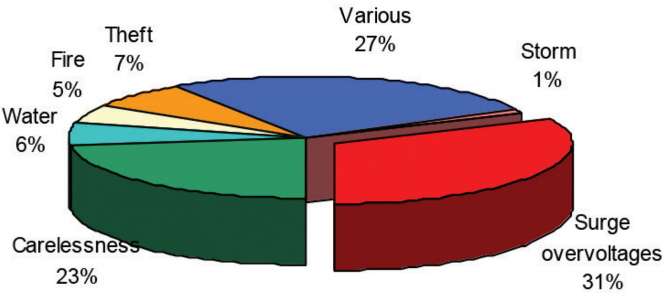


Figure 9 Damage to Electronic Devices due to Surge Overvoltages

Figure 10 shows the damage on the power system plant including all equipment used in power system distribution and transmission network. Of course this is a very general approach and also includes isolated transmission lines exposed to direct lightning strokes, but it represents an actual statistical survey that should be taken into consideration.

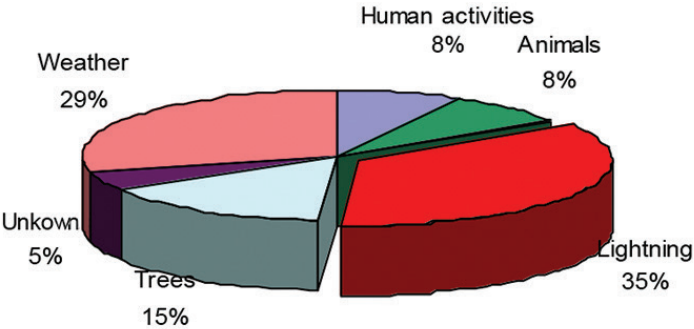


Figure 10 Damage on Power System Distribution Plant due to Lightning Strokes

SOME LIGHTNING PARAMETERS OF INTEREST

Ground Flash Density

This is a fundamental parameter, providing the basis for any estimation of the frequency of lightning effects on electrical system. The ground flash density N_g is often viewed as the primary descriptor of lightning incidence, at least in lightning protection studies. Ground flash density has been estimated from records of (1) lightning flash counters (LFCs) and (2) lightning locating systems (LLSs) and can potentially be estimated from records of satellite-based optical or radio-frequency radiation detectors. It is worth noting that satellite detectors cannot distinguish between cloud and ground discharges and, hence, in order to obtain N_g maps from satellite observations, a spatial distribution of the fraction of discharges to ground relative to the total number of lightning discharges is needed. IEEE Std 1410-2010 recommends that in the absence of ground-based measurements of N_g, N_g is assumed to equal to one-third of the total flash density (including both cloud and ground discharges) based on satellite observations.

The ground flash density N_g for temperate areas may be estimated from T_d, the keraunic level, using Equation (1) from Anderson *et al.*:

$$N = 0.04 T_d^{\,1.25} \qquad (1)$$

where

N_g is the ground flash density in flashes per km^2 per year

T_d is the number of days with thunder per year

CIGRE Task Force C4.01.02-B noted that this expression has unacceptably large errors in tropical areas, recommending the alternative expressions for Equation (1), as tabulated in Table 4.

Table 4 Alternative Expressions for Equation 1 for Tropical Areas.

Country	Alternative Expression for Equation (1)
Mexico	$N = 0.024T_d^{1.12}$
Brazil	$N = 0.030T_d^{1.12}$
Columbia	$N = 0.0017\ T_d^{1.56}$

Figure 11 shows isokeraunic level (thunder days per year) in Malaysia. The western cost, especially the Klang valley records the highest lightning densities.

These values are almost an order of magnitude greater than the global average. IEC 62305-2:2010 specifies approximate relationship of the lightning density N_g with keraunic level or thunder days per year (T_d) for temperate land only, as expressed in Equation (2)

$$N_g = 0.1\ T_d \qquad (2)$$

where

N_g is the ground flash density in flashes per km^2 per year

T_d is the number of days with thunder per year

Figure 11 Malaysian Lightning Density Map Given in Terms of Thunder Days Per yYar (adopted from)

Alternatively, GFD may directly be obtained from the Lightning Detection System Network (LDSN), operated by TNB Research (TNBR); where a typical GFD map is shown in Figure 12.

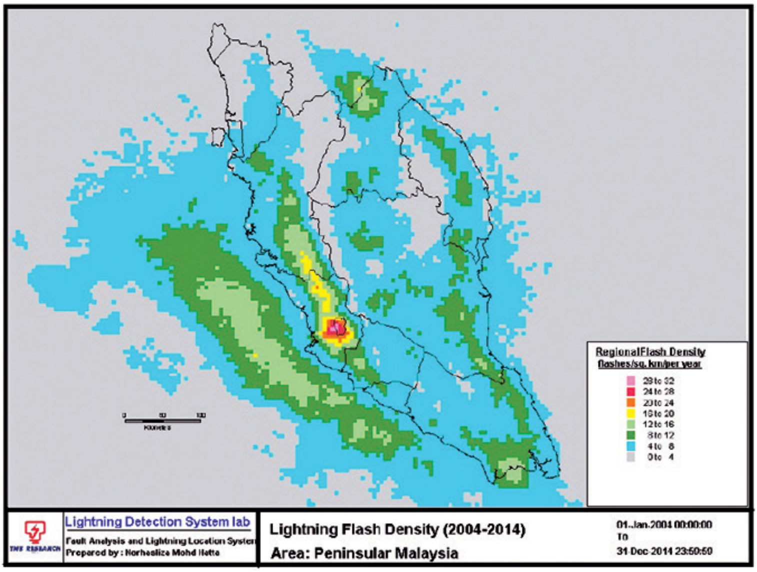


Figure 12 Ground Flash Density (GFD) Map for Peninsula Malaysia (Courtesy from TNBR)

Peak Current – "Classical" Distribution

All national and international lightning protection standards (e.g., IEEE Std 1410-2010; IEEE Std 1243- 1997; IEC 62305 series) include a statistical distribution of peak currents for first strokes in negative lightning flashes (including single-stroke flashes). This distribution, which is one of the foundations of most lightning protection studies, is largely based on direct lightning current measurements conducted in Switzerland from 1963 to 1971.

Directly measured current waveforms of either polarity found in the literature do not exhibit peaks exceeding 300 kA or so, although inferences from remotely measured electric and magnetic fields suggest the existence of currents up to 500 kA and even higher.

For the CIGRE distribution, 98% of peak currents exceed 4 kA, 80% exceed 20 kA, and 5% exceed 90 kA. For the IEEE distribution, the "probability to exceed" values are given by the following Equation (3)

$$P(I) = \frac{1}{1 + (\frac{I}{31})^{2.6}} \qquad (3)$$

where P(I) is in per unit and I is the first return stroke peak current in kA. This equation applies to values of I up to 200 kA.

This equation, usually assumed to be applicable to negative first strokes, is based on data for 624 strokes analysed by Popolansky, whose sample included both positive and negative strokes, as well as strokes in upward lightning.

The distribution of subsequent-stroke peak current values is approximated in Equation (4) by (IEEE Std 1243-1997:

$$P(I) = \frac{1}{1 + (\frac{I}{12})^{2.7}} \qquad (4)$$

Sample sizes for "global"peak current distributions for negative first strokes and the IEEE peak current distributions can be referred to CIGRE Technical Brochure (TB) 549.

Table 5 shows the global peak current distribution derived from equations (2) and (3). However, these distributions are not much different from the direct current measurement by Berger *et al.* (1975) which are still regarded as the most reliable ones.

Table 5 The IEEE Peak Current Distributions (adopted from)

Peak current, I, kA		5	10	20	40	60	80	100	200
Percentage exceeding tabulated value, P(I) · 100%	First strokes	99	95	76	34	15	7.8	4.5	0.78
	Subsequent strokes	91	62	20	3.7	1.3	0.59	0.33	0.050

In the protection concerns, the lightning current has been divided into two parts in order to represent the impulse component and the long continuing current. The two components are

1. Short strokes (impulse) with duration of less than 2 ms (Figure 13)
2. Long strokes with duration of longer than 2 ms and less than 1 s (Figure 14).

In IEC 62305-1, test current waveform with T_1= 8 μs and T_2 =20 μs (known as 8/20 μs impulse) and another with T_1= 10 μs and T_2=350 μs (known as 10/350 μs impulse) have been recommended.

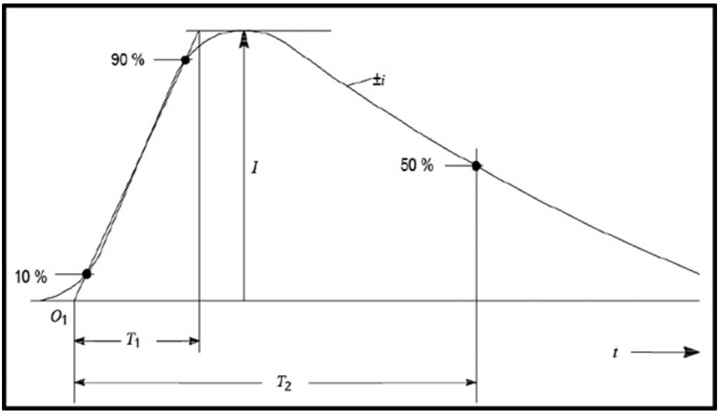


Figure 13 The short stroke current (impulse) as specified in IEC 62305-1.

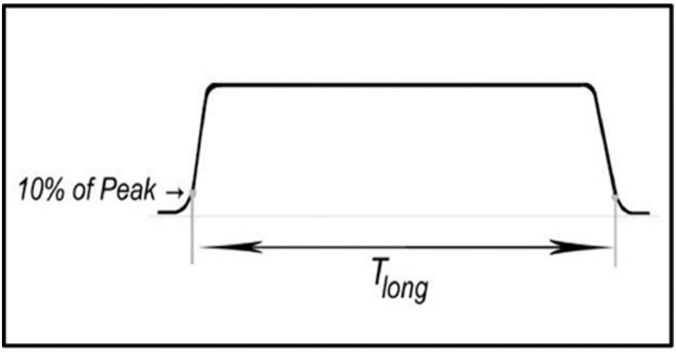


Figure 14 The long stroke current (continuing current) specified in IEC 62305-1:2010. T_{long} can vary between 2 ms to 1000 ms.

Peak Current – Direct Measurement

Recently, direct current measurements on instrumented towers were carried out in Russia, South Africa, Canada, Germany, Brazil, Japan, Austria, and again in Switzerland (on a different tower). Important results from the Brazilian, Japanese, and Austrian studies are reviewed and compared with Berger's data. In addition, recent direct current measurements for rocket-triggered lightning are also considered. Reference summarised the distributions of lightning peak currents from individual studies (obtained from direct measurements only) and those synthesised by combining different measurements for first and subsequent stroke.

Other Parameters of Interests

Apart from those basic parameters discussed earlier, there are several other lightning parameters needed in engineering applications including maximum current derivative, average current rate of rise, current risetime, current duration, charge transfer, and specific energy (action integral), which are all derivable from direct current measurements.

Distributions of these parameters presently adopted by CIGRE are based on direct measurements by Berger and co-workers in Switzerland. There are also more recent direct current measurements available which are obtained using instrumented towers in Austria, Brazil, Canada, Germany, Japan, Russia, and Switzerland, as well as those obtained in several countries using rocket-triggered lightning. Furthermore, modern lightning locating systems report peak currents estimated from measured magnetic or electric field peaks. Additionally, lightning parameters such as the number of strokes per flash (multiplicity), interstroke interval, number of channels per flash, relative intensity of strokes within a flash, return-stroke speed, and equivalent impedance of the lightning channel, as well as characteristics of continuing currents and M-components are among other parameters to be considered. Table 8 shows lightning current parameters (based on Berger's data) recommended by CIGRE TB 549 and IEEE Std 1410-2010.

Table 8 Lightning Current Parameters (Based on Berger's Data) Recommended by CIGRE TB 459 and IEEE Std 1410-2010

Parameters of log-normal distribution for negative downward flashes				
Parameter	**First stroke**		**Subsequent stroke**	
	***M*, Median**	**β, logarithmic (base e) standard deviation**	***M*, Median**	**β, logarithmic base standard deviation**
FRONT TIME (μs)				
$t_{d10/90} = T_{10/90}/0.8$	5.63	0.576	0.75	0.921
$t_{d30/90} = T_{30/90}/0.6$	3.83	0.553	0.67	1.013
$t_m = I_F / S_m$	1.28	0.611	0.308	0.708
STEEPNESS (kA/μs)				
S_m, Maximum	24.3	0.599	39.9	0.852
S_{10}, at 10%	2.6	0.921	18.9	1.404
$S_{10/90}$, 10-90%	5.0	0.645	15.4	0.944
$S_{30/90}$, 30-90%	7.2	0.622	20.1	0.967
PEAK (CREST) CURRENT (kA)				
I_I, initial	27.7	0.461	11.8	0.530
I_F, final	31.1	0.484	12.3	0.530
Ratio, I_I/I_F	0.9	0.230	0.9	0.207
OTHER RELEVANT PARAMETERS				
Tail Time to Half Value t_h (μs)	77.5	0.577	30.2	0.933
Number of strokes per flash	1	0	2.4	0.96 based on median N_{total}=3.4
Stroke Charge, Q_I (Coulomb)	4.65	0.882	0.938	0.882
$\int I^2 dt$ ((kA)^{2}s)	0.057	1.373	0.0055	1.366
Interstroke interval (ms)	—	—	35	1.066

KNOWLEDGE CONTRIBUTION ON LIGHTNING PROTECTION SYSTEM SOLUTIONS

This particular section highlights some of the knowledge contributions that have significantly been achieved by the author and his group.

Lightning Location System for Forensic Case Study

This section details out the incident that caused death to a man living in the palm estate area in Lukut Negeri Sembilan. That incident was covered in most of the newspapers in Malaysia and reported to have happened around 5.30 pm (local time) on 27 November 2011. There are few issues here i.e. the death incident, the electrical shock to personnel and damage to equipments. While the death is very rare in this case (where family claimed to see the red flash coming from the front door), it is believed that it was due to the flashover from the roof to the victim that happened within a fraction of a second, as reported by family members.

Some information that we received from the electrical utility showed that between 4.00-6.00 pm on the 27 Nov 2011 (the date when the incident happened), there were about 155 lightning strikes within 10 km radius from the locations of the accident with two of the strikes carried 105 kA (6.01 pm) and 114 kA (5.35 pm). This is a huge amount of current that more than enough to cause damage to person and equipment (from various mechanisms). Figure 15 shows the number of lightning strikes at 10 km radius from the incident location, recorded for the period of 45 days, from 1 Nov 2011 till 15 Dec 2011. Due to the difficulty in getting the coronary report, we were unable to discuss further details of the incident from the medical point of view. Nevertheless, there were very good idea on the technical perspective such as on the peak current, location from the incident and number of strike which definitely would be useful in designing the lightning protection system. This is a very good example how one can utilise these lightning parameters to investigate the details pertaining to the incident, which in this case was found to be very informative.

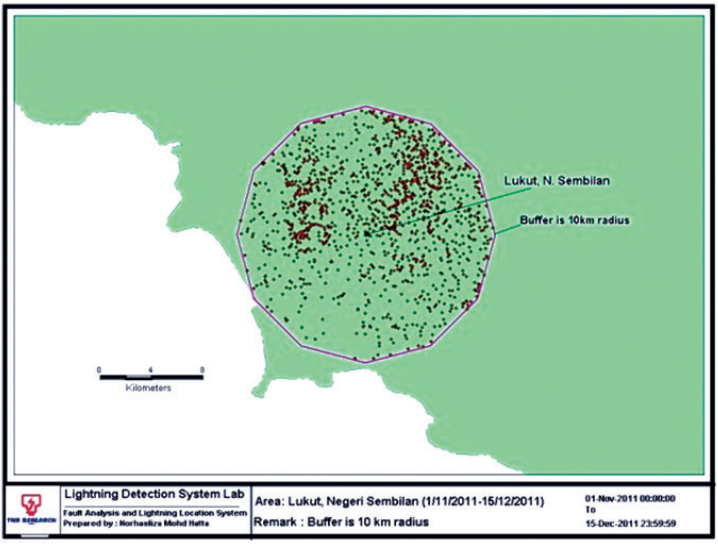


Figure 15 Lightning Recorded Data within 10 km Radius from the Incident Location

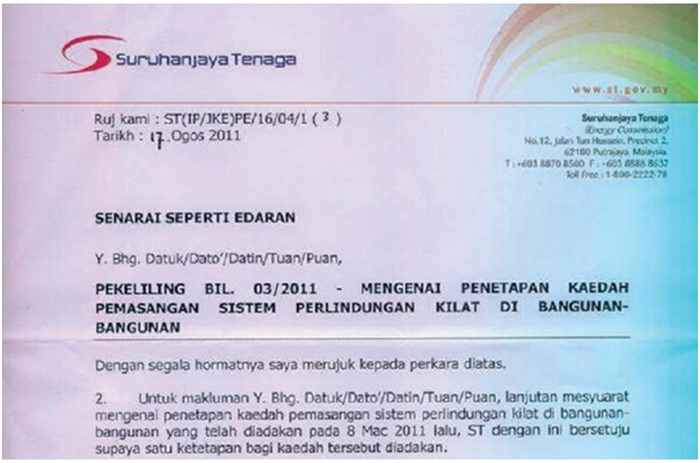
Standard and Policy Development

Lightning parameters are of interest in different fields of research and engineering applications, such as airborne vehicles, construction and oil industry engineering, power network components and wind turbines. The protection against lightning for each application follows specific standards.

In the case of transmission lines for instance, the protection is mainly based on the use of shield wires (or overhead ground wires) and selective use of surge arresters. Some special methods have also been successfully used for improving the lightning performance. The grounding system has generally exerted a great influence on the effectiveness of the protection means. In the IEC 62305 series, these parameters form the basis of the developed standard for the protection of structures, living beings and electrical and electronic systems against lightning.

Effective shield wire protection is characterised by low probability of both shielding failures and backflashovers. Modelling and procedures for the estimation of these probabilities have been addressed by both CIGRE document and IEEE Standards.

Malaysia adopted the relevant IEC standard in 2007, known as the MS IEC 62305:1-4. However, comprehensiveness and completeness MS IEC 62305 (2007) makes the document difficult to understand by engineers in particular specialisation. As seen in many countries including Malaysia, the difficulty can make the engineer fail to comply with the standard and this has resulted in choosing the non – standard or unrecognised system offered by providers with a simple design. This has led toward a possible dangers that threaten public safety. Soon after the circular on Lightning Protection System (LPS) was issued by the Energy Commission of Malaysia, Centre for Electromagnetic and Lightning Protection Research (CELP), UPM has been mandated to come out with the guidebook that could ease and guide the consumers to the relevant aspect in the standard. "Lightning Protection Systems Handbook" was created to bridge the gap electrical engineer general knowledge about MS IEC 62305 (2007). This book was released in 2014 by the Energy Commission of Malaysia. Figures 16 to17 shows the partial page of the circular, released in 2011 and the front page of the handbook, respectively.



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SENARAI SEPERTI EDARAN

Y. Bhg. Datuk/Dato'/Datin/Tuan/Puan,

PEKELILING BIL. 03/2011 - MENGENAI PENETAPAN KAEDAH PEMASANGAN SISTEM PERLINDUNGAN KILAT DI BANGUNAN-BANGUNAN

Dengan segala hormatnya saya merujuk kepada perkara diatas.

2. Untuk makluman Y. Bhg. Datuk/Dato'/Datin/Tuan/Puan, lanjutan mesyuarat mengenai penetapan kaedah pemasangan sistem perlindungan kilat di bangunan-bangunan yang telah diadakan pada 8 Mac 2011 lalu, ST dengan ini bersetuju supaya satu ketetapan bagi kaedah tersebut diadakan.

Figure 16 Circular on Lightning Protection System Installation for Buildings Released in 2011 by the Energy Commission of Malaysia

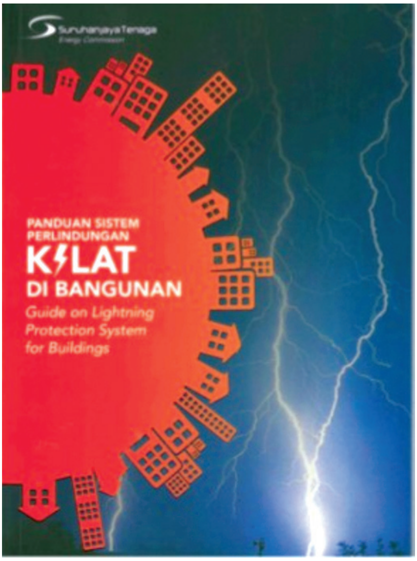

Figure 17 Guide on Lightning Protection Systems for Buildings, published by the Energy Commission of Malaysia in 2014

In 2016, another milestone was achieved and marked the important aspect and contribution of lightning protection in Malaysia. Due to many issues and complaints by the customers on the damages to their solar photovoltaic (pv) system, Sustainable Energy Development Authority (SEDA) has taken the initiative to develop the guidebook on lightning protection for photovoltaic (PV) systems. Again, CELP has been given another responsibility to prepare this guidebook. After several months of discussion, the guidebook, known as Lightning Protection for Photovoltaic (PV) Systems, was released in August 2016 and made available to the public, which include the solar PV system owner and the certified designer and installer. Figure 18 depicts the front page of this guidebook.

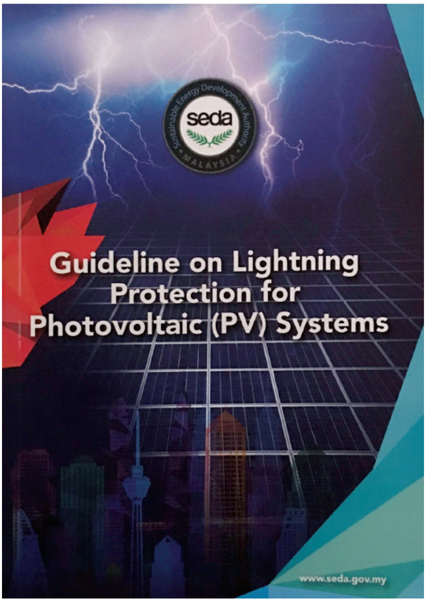

Figure 18 Guideline on Lightning Protection for PV Systems published by Sustainable Energy Development Authority (SEDA) in 2016

Characterisation of Lightning Generated Electric Fields

After several years of effort, the Automated Characterisation of Lightning Electric Fields – Center of Electromagnetic and Lightning Protection (ACLEF-CELP) was finally developed at CELP. This system able to characterise various parameters for preliminary breakdown pulses (PBP) and return stroke (RS), which include the Width Half Maximum first derivative (T_{FWHM_dedt}), Peak amplitude first derivative (E_{dedt}), peak time first derivative (T_{peak_dedt}), Full Width Half Maximum (T_{FWHM}), Slow Front amplitude (E_{sf}), slow front time (T_{sf}), 10 to 90 % time ($T_{10\text{-}90}$), Peak amplitude (E_p), peak time (T_p) and zero crossing time (T_{zc}) of return stroke. For PBP, there is duration before return stroke ($T_{pbp\text{-}rs}$), duration (T_{pbp}), peak (E_{pbp}) and peak time ($T_{peakpbp}$) of Preliminary Breakdown Pulses for PBP part.

Figure 19 illustrates the user-friendly Graphical User interface (GUI) that was created in Matlab. It also displays the full raw signal and every single PBP and RS signal that occurred at that time. It also shows the type of lightning i.e. positive or negative return stroke. It is the first of its kind that has been developed based on a comprehensive criteria established for each parameter.

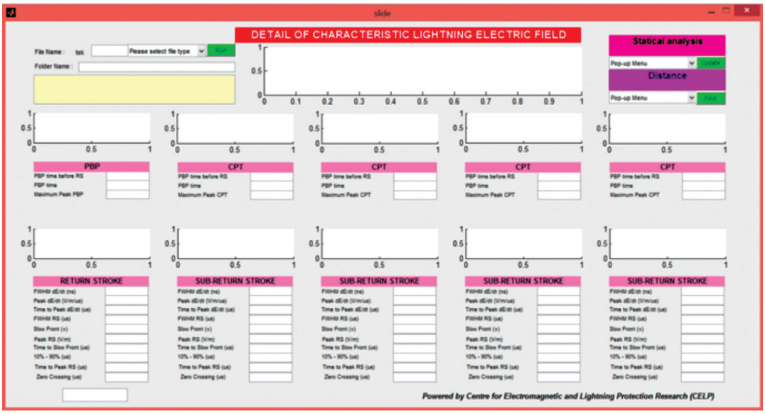

Figure 19 The GUI for Automated Characterisation of Lightning Electric Fields – Centre of Electromagnetic and Lightning Protection (ACLEF-CELP)

Novel Development of Lightning Location Systems

Advance lightning detection network (LDN) were introduced with smart sensors placed at strategic location to measure ground flash density (GFD). Sensors are able to detect real-time lightning activity and software is able to analyse historical data, which computes to the GFD map. Lightning data in term of time, flash location, polarity, peak current of return stroke, and stroke multiplicity are measured and displayed for analysis.

The sensors use Time-of-arrival (TOA) and Magnetic Direction Finding (MDF) method in order to satisfy the accuracy and efficiency requirements. With an accuracy of +/-500 m and 95% detection efficiency, the system is able to detect lightning in the range of 600 km from the sensors. However, the drawback of the current method is the ability to provide the full waveshape of lightning current waveform and the electromagnetic field (EMF). As far as research and development are concerned, this is very crucial information especially for surge arrester studies i.e. selection of surge arrester rating and its placement.

Taking into account all these problems and gaps, we have developed novel lightning location system based on two stations measurement as depicted in Figure 20.

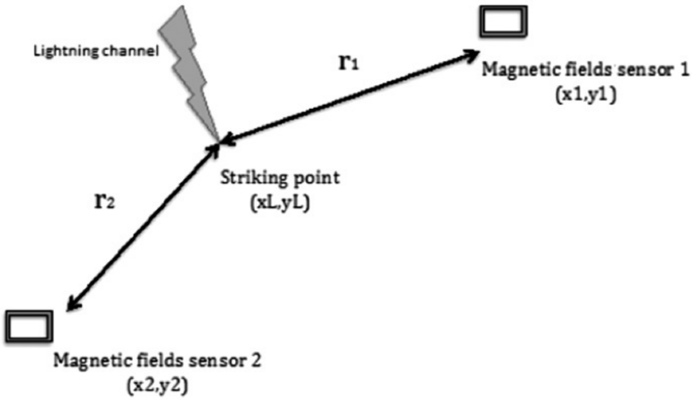

Figure 20 Problem Geometry of the Developed Method

In principle, the developed model works based on inversed procedure technique whereby two magnetic field sensors were set at two known positions with related coordinates of (x_1,y_1) and (x_2,y_2), respectively. In contrast, the lightning stroke position was unknown and set at (x_L,y_L). The radial distance between the lightning channel and sensors 1 and 2 will be r_1 and r_2, respectively. The generated magnetic fields from the two sensors will be used to feed the developed algorithm, taking into account all the relevant and known parameters such as the ground conductivity and distance between the sensors. The developed technique will finally provide the solution to all the unknown parameters such as the stroke location, electric fields, peak current magnitude, polarity, return stroke velocity and full waveshape of lightning current waveform, as opposed to the existing techniques or solutions.

CONCLUSION

This inaugural lecture highlights the lightning severity in Malaysia and has summarised some of the basic and important lightning parameters that are needed in power engineering calculations and applications, along with relevant references to standards and recent literatures on the subject. Looking at several engineering applications with regards to the obtained parameters, the use of these parameters in the standard series of IEC 62305 and several other IEEE standards for instance are mainly based on the direct measurements by Berger and co-workers in Switzerland. Meanwhile, more recent direct current measurements were obtained from instrumented towers in Austria, Germany, Russia, Canada, and Brazil, as well as from rocket-triggered lightning. Further, modern lightning locating systems (LLS) reported the peak current estimated from measured electromagnetic field peaks, which can lead to many improvements of the existing research and technologies in lightning detection and protection. In the meantime, new perspectives of lightning research could also be explored.

REFERENCES

Ab Kadir, M. Z. A., Misbah, N. R., Gomes, C., Jasni, J., Wan Ahmad, W. F., & Hassan, M. K. (2012). *Recent statistics on lightning fatalities in Malaysia*. 31st International Conference on Lightning Protection (ICLP), pp. 1-5, Vienna.

Ab Kadir, M.Z.A., Mohd Nawi, Z., & Sardi, J. (2010). Numerical modeling and simulation in electromagnetic transient program for estimating line backflashover performance. *IAENG-Engineering Letters*, *18*(4), 351-356.

Ab. Kadir, M.Z.A. (2016). Lightning severity in Malaysia and some parameters of interest for engineering application. *Thermal Science*, *20*(2), S437-S450.

Ab. Kadir, M.Z.A., & Izadi, M. (2010). New algorithm for evaluation of electric fields due to indirect lightning strike. *Computer Modeling in Engineering Science (CMES)*, *67*(1), 1-12.

Ab Kadir, M.Z.A., & Cotton, I. (2010). Application of the Insulator Coordination Gap Models and effect of line design to backflashover studies. *International Journal of Electrical Power and Energy System*, *32*(5), 443-449.

Abd Rahman, M.S.B., Izadi, M., & Ab-Kadir, M.Z.A. (2015). The electrical behaviour of polymer insulator under different weather conditions. *Applied Mechanics and Materials*, *793*, 60-64.

Abdul Rahim, N., Izadi, M., Ab Kadir, M.Z.A., Gomes, C., Hasni, J., & Rameli, N. (2014). *The behaviour of lightning current and charge density in the case of tall tower*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Aini, M.S., Elistina, A.B., Ab Kadir, M.Z.A., Gomes, C., & Keul, A.G. (2014). *The influence of socio demographic factors on severe weather concern, knowledge and preparedness among Malaysians*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Alexander Keul, Bernhard Brunner, Melanie Korff, Sanjay Sharma, Partha Roy, John Allen, Katie A. Bowden, Aini Mat Said, Elistina Abu Bakar, Mohd Zainal Abidin Ab Kadir, Chandima Gomes, & Mateusz Taszarek. *Severe weather and psychology - Analysis of international survey data*. 8th European Conference on Severe Storms, pp.14-18. September 2015, Wiener Neustadt, Austria.

Anderson, R. B., Eriksson, A. J., Kroninger, H., Meal, D. V., & Smith, M. A. *Lightning and thunderstorm parameters*. IEE Conference Publication no. 236, Lightning and Power Systems, London, June 1984, pp. 57–61.

Anderson, R. B., & Eriksson, A. J. (1980). Lightning parameters for engineering application. ELECTRA, *69*, 65-101.

Ariffen, A.M., Ab-Kadir, M.Z.A., Gomes, C., Jasni, J., &Arshad, S.N.M. (2015). The electric field effect on angles of copper-type down-conductor. *Applied Mechanics and Materials*, *793*, 24-28.

Arshad, S.N.M., Izadi, M., Ab Kadir, M.Z.A., Abd Bari, M.A., Rameli, N., Abdul Rahim, N., & Hamzah, M.N. (2014). *Characterization preliminary breakdown in the measured lightning electric fields*. IEEE 8th International Power Engineering and Optimization Conference (PEOCO 2014), Langkawi,Malaysia.

Arshad, S.N.M., Ab Kadir, M.Z.A., Izadi, M., Hamzah, M.N., Gomes, C., & Jasni, J. (2014). *Characterization of measured lightning electric fields observed in Malaysia*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Ashen Gomes, Chandima Gomes, & Zainal Kadir. (2016). *Evaluation of lightning protection systems proposed for small structures by electromagnetic simulation*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Berger, K.,Anderson, R. B., & Kroninger, H. (1975). Parameters of lightning flashes. *ELECTRA*, *41*, 23-37.

Charalambous, C.A., Kokkinos, N., Christofides, N., Ab Kadir, M.Z.A., & Gomes, C. (2014*). A simulation tool to assess the lightning induced overvoltages on DC cables of photovoltaic installations*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Cherchiglia, L. C. L., Cazetta Fo, A, dos Reis, R. J., & Amorim, G. E. S. (2002). CEMIG experience in improving transmission line lightning performance using a Lightning Location System, CIGRE Paris Session.

CIGRE Task Force C4.01.02-B, "Ground Flash Density: definition of the appropriate grid size and a proposal of relationship Ng vs. Td for Tropical zones," Activity Report, CIGRE WG C4.01 Meeting, Dallas, Texas, Sept. 2003.

CIGRE WG C4.407, Technical Brochure 549. Lightning Parameters for Engineering Applications, 61 p., 2013.

Energy Commission of Malaysia. Guide on Lightning Protection System for Buildings. ISBN: 978-967-12023-4-0. 2014 (M.Z.A. Ab-Kadir -Contributor)

Farah Adilah Jamaludin, Mohd Zainal Abidin Ab Kadir, Mahdi Izadi, Norhafiz Azis, Jasronita Jasni, & Mohammad Syahmi Abd Rahman. (2016). *Considering the effects of a RTV Coating to improve electrical insulation against lightning*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Fleenor, S., Biagi, C., Cummins, K., Krider, E., & Shao, X. (2009). Characteristics of cloud-to-ground lightning in warm-season thunderstorms in the Central Great Plains. *Atmospheric Research*, *91*(2-4), 333-352..

Foster Chileshe Lubasi, Chandima Gomes, Mohd Zainal Abidin Ab Kadir, & Mary Ann Cooper. (2012). Case Studies of Lightning Related Injuries and Property Damage in Zambia. International Conference on Lightning Protection (ICLP), Vienna, Austria.

Gomes, C., & Ab. Kadir, M.Z.A. (2011). Lightning protection: Getting it wrong. IEEE Technology and Society Magazine (Cover Article), *30*(2)

Gomes, C., Cooray, V., & Ab. Kadir, M.Z.A. (2013). Vertical electric fields and field change parameters due to partly inclined lightning leader channels. *Progress in Electromagnetic Research (PIER)*, *135*, 55-80.

Gomes, C., & Kadir, Z. (2015). Efficient lightning protection: Optimization of economic, environmental and safety aspects. *Environmental Engineering and Management Journal*, *14*(8), 1975-1985.

Cooper, M.A., & Ab Kadir, M.Z.A. (2010). *Lightning injury continues to be a public health threat internationally*. International Lightning Meteorology Conference (ILMC), Orlando, Florida, USA, April 21-22.

Cooper, M.A., Ab Kadir M.Z.A., & Gomes, C. (2011). Electrical and Lightning Injuries for Textbook of Emergency Medicine.Wolters Kluwer Health (Lippincott, Williams and Wilkins), Delhi India.

Gillespie, J. A. T., & Stapleton, G. (2004). *Improving double circuit transmission line reliability through lightning design*. In CIGRE 2004, pp. 1–8.

Gomes, C., & Kadir, Z. (2011).A theoretical approach to estimate the annual lightning hazards on human beings. *Atmospheric Research*, *101*(3), 719-725,

Guideline on Lightning Protection for Photovoltaic (PV) Systems. Published by Sustainable Energy Development Authority (SEDA) Malaysia, July 2016. (M.Z.A. Ab-Kadir -Contributor)

Hajikhani, M., Ab-Kadir, M.Z.A., Izadi, M., Gomes, C., & Jasni, J. (2016). *Lightning fatalities and injuries in Malaysia from 2008 to 2015*. 33rd International Conference on Lightning Protection (ICLP), Estoril Portugal.

Hamzah, M.M., Ab Kadir, M.Z.A., Gomes, C., Arshad, S.N.M., Abdullah, N., & Hatta, N.M. (2014). *Unusually long duration lightning electric field return strokes in Malaysia*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Hamzah, M. N., Ab-Kadir, M. Z. A., Gomes, C., & Arshad, S. N. M. (2015). Unique stroke- multiplicity of positive lightning in Malaysia. *Applied Mechanics and Materials*, *793*, 39-43.

Heidler, F., & Hopf, C. (1998). Measurement results of the electric fields in cloud-to- ground lightning in nearby Munich, Germany. *IEEE Transactions on Electromagnetic Compatibility*, *40*(4), 436-443.

IEC Standard 62305-1: 2010. Protection against lightning-Part 1: General principles, Edition 2.0. 2010 (M.Z.A. Ab-Kadir –Contributor)

IEC Standard 62305-2: 2010. Protection against lightning –Part 2:Risk management, Edition 2.0, 2010

IEC Standard 62305-3: 2010. Protection against lightning - Part 3: Physical damage to structures and life hazard, Edition 2.0, 2010

IEC Standard 62305-4: 2010. Protection against lightning - Part 4: Electrical and electronic systems within structures, Edition 2.0. 2010

IEEE Standard 1410-2010. IEEE Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines, 2010.

IEEE Std 1243-1997. IEEE Guide for Improving the Lightning Performance of Transmission Lines, 1997.

Izadi, M., Ab-Kadir, M. Z. A., & Hajikhani, M. (2013). Considering on the ground reflection effect on the electromagnetic fields due to lightning channel. *J. Electrical Engineering and Technology (JEET)*, *8*(4), 824-831.

Izadi, M., Ab Kadir, M.Z.A., & Hajikhani, M. (2014). Evaluation of lightning current and ground reflection factor using measured electromagnetic field. *Applied Computational Electromagnetics Society Journal*, *29*(1), 107 – 115.

Izadi, M., Ab Kadir, M.Z.A., & Hajikhani, M. (2015). On the lightning electromagnetic fields due to channel with variable return stroke velocity. *Mathematical Problems in Engineering*, 1-9.

Izadi, M., Ab-Kadir, M.Z.A., Abd-Rahman, M.S., Jamaluddin, F.A., & Azis, N. (2016). *Electrical performance of 10kV polymer insulator under lightning induced voltage condition*. CIGRE Paris Session.

Izadi, M., Ab-Kadir, M.Z.A., Chia, S.C., Jasni, J., & Gomes, C. (2016). *Effect of parallel 275kV transmission line with oil pipeline on electromagnetic field calculation*. CIGRE Paris Session.

Izadi, M., Ab. Kadir, M.Z.A., & Gomes, C. (2011). Evaluation of electromagnetic fields associated with inclined lightning channel using Second Order FDTD-Hybrid Methods. *Progress in Electromagnetic Research (PIER)*, *117*, 209-236.

Izadi, M., Ab. Kadir, M.Z.A., Cooray, V., & Hajikhani, M. (2014). Estimation of lightning current and return stroke velocity profile using measured electromagnetic fields. *Electric Power Components and Systems*, *42*(2), 103-111.

Izadi, M., Ab. Kadir, M.Z.A., Gomes, C., & Cooray, V. (2012). Evaluation of lightning return stroke current using measured electromagnetic fields. *Progress in Electromagnetic Research (PIER)*, *130*, 581-600.

Izadi, M., Ab. Kadir, M.Z.A., Gomes, C., Cooray, V., & Schoene, J. (2012). Evaluation of lightning current and velocity profiles along lightning channel using measured magnetic flux density. *Progress in Electromagnetic Research (PIER)*, *130*, 473- 492.

Izadi, M., Ab. Kadir, M.Z.A., Gomes, C., & Wan Ahmad, W.F. (2010). An analytical Second-FDTD Method for evaluation of electric and magnetic fields at intermediate distances from lightning channel. *Progress in Electromagnetic Research (PIER)*, *110*, 329-352.

Kokkinos, K. (2005).*Transient behavious of low voltage systems due to lightning strikes*. PhD Thesis, UMIST.

Lim, S.C., Gomes, C., & Ab. Kadir, M.Z.A. (2013). Electrical earthing in troubled Environment. *International Journal of Electrical Power and Energy System*, *47*, 117-128.

Lim, S.C., Gomes, C., & Ab Kadir, M.Z.A. (2016). Behaviour of a new material that improves ufer grounding practice. *Journal of Electrical Systems*, *12*(2), 291- 300.

Lim, S.C., Gomes, C., Ab Kadir, M.Z.A., Nourirad, G., & Malek, Z.A. (2015). Behaviour of backfill materials for electrical grounding systems under high voltage conditions. *Journal of Engineering Science and Technology*, *10*(6), 811-826.

Lim, S.C., Gomes, C., Ab Kadir, M.Z.A., Nourirad, G., & Malek, Z.A. (2015). Behaviour of backfill materials for electrical grounding systems under high voltage conditions. *Journal of Engineering Science and Technology*, *10*(6), 811-826.

Lim, S.C., Ab Kadir, M.Z.A., Gomes, C., & Azis, N. (2014). *Steady state performance of improvised ufer grounding practice*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Mahdi Izadi, Mohd Zainal Abidn Ab Kadir, Maryam Hajikhani, & Chandima Gomes. (2016). *Evaluation of lightning location and lightning current wave shape using measured lightning magnetic fields at two stations*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Maryam Hajikhani, Mohd Zainal Abidin Ab Kadir, Mahdi Izadi, Chandima Gomes, & Jasronita Jasni. (2016*). A comparison of lightning human fatalities between Malaysia and United States*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Maryam Hajikhani, Mohd Zainal Abidin Ab Kadir, Mahdi Izadi, & Jasronita Jasni. (2016). *Lightning fatalities and injuries in Malaysia from 2008 to 2015*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Misbah, N.R., Ab Kadir, M.Z.A., & Gomes, C. (2011). *Modelling and analysis of different aspect of mechanisms in Lightning Injury*. 4th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO), Kuala Lumpur, pp. 1-5.

Mohamed Rawi, I., & Ab Kadir, M.Z.A. (2016). A case study and observation on cause of transmission line outages in Malaysia", CIGRE Paris Session.

Mohamed Rawi, I., & Ab Kadir, M.Z.A (2015). *Investigation on the 132kV overhead lines lightning-related flashovers in Malaysia*. International Symposium on Lightning Protection (XIII SIPDA), Brazil, pp. 239-243.

Mohamed Rawi, I, Ab-Kadir, M.Z.A., & Izadi, M. (2016). *Seasonal variation of transmission line outages in Peninsular Malaysia*. International Conference on Electrical & Electronic Technology (ICEETech), Kuala Lumpur.

Muhammad Syahmi Bin Abd Rahman, Mahdi Izadi, & Mohd Zainal Abidin Ab Kadir. (2014). *Influence of air humidity and contamination on electrical field of polymer insulator*. IEEE International Conferences on Power Energy (PECON 2014), Kuching Sarawak, Malaysia.

Muhammad Syahmi Bin Abd Rahman, Mahdi Izadi, Mohd Zainal Abidin Ab Kadir, Chandima Gomes, Jasronita Jasni, & Farah Adillah Jamaludin. (2016). *Evaluation of electromagnetic fields on polluted polymer insulator under lightning impulse current*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Nag, A., & Rakov, V. A. (2012). Positive lightning: An overview, new observations, and inferences. *J. Geophys. Res*., 117.

Naval Systems against Electromagnetic Effects Due to Lightning. Progress in Electromagnetic Research (PIER), Vol. 113, pp 333-349, 2011.

Norhidayu Rameli, Mohd Zainal Abidin Ab Kadir, Mahdi Izadi, Chandima Gomes, & Norhafiz Azis. (2016). *Effect of soil resistivity on magnetic field in the case of lightning strike to a tall structure*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Norhidayu Rameli, Mohd Zainal Abidin Ab Kadir, Mahdi Izadi, Chandima Gomes & Norhafiz Azis. (2016). *Variations in return stroke velocity and its effect on the return stroke current along lightning channel*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

Nourirad, G., Izadi, M., Gomes, C., & Ab Kadir, M.Z.A. (2014). *Lightning safety against side flashes: Influence of floating electrodes on gap breakdown*. International Conference on Lightning Protection (ICLP), Shanghai, China.

Pekeliling Bil. 03/2011: Penetapan Kaedah Pemasangan Sistem Perlindungan Kilat di Bangunan-Bangunan, ST (IP/JKE)PE/16/04/1(3). (M.Z.A. Ab-Kadir -Advisor)

Popolansky, F. (1972). Frequency distribution of lightning currents. *ELECTRA 22*, 139-147.

Qie, X., Wang, Z., Wang, D., & Liu, M. (2013). Characteristics of positive cloud to- ground lightning in Da Hinggan Ling forest region at relatively high latitude, northeastern China. *J. Geophys. Res. Atmos*., *118*(24), 393-13.

Rameli, N., Ab Kadir, M.Z.A., Izadi, M., Gomes, C., & Azis, N. (2015). The effect of the grounding system on the lightning current profile along tall structure. *IET Science*, *Measurement* & *Technology*, *9*(6), 717 – 727.

Rameli, N., Ab-Kadir, M.Z.A., Izadi, M., Gomes, C., Azis, N., & Arshad, S.N.M. (2015). Consideration of lightning current along a tall structure in the presence of horizontal arrangement grounding. *Applied Mechanics and Materials*, *793*, 34-38.

Rusli, H., Gomes, C., Kadir, Z., & Abdul-Malek, Z. (2015). Surface arcing of insulators due to bentonite contamination.Journal of Electrostatics, *76*, 73-77.

Rakov, V. A., & Uman, M A. (2007). *Lightning*: *Physics and effects*. Cambridge Univ. Press.

Saba, M. M. F., Schulz, W., Warner, T. A., Campos, L. Z. S., Schumann, C., Krider, E. P., Cummins, K. L., & Orville, R. E. (2010). High-speed video observations of positive lightning flashes to ground. *J. Geophys. Res*., 115, D24201.

Thien, Y.V., Azis, N., Jasni, J., Ab Kadir, M.Z.A., Yunus, R., Ishak, M.T., & Yaakub, Z. (2016). The effect of polarity on the lightning breakdown voltages of palm oil and coconut oil under a non-uniform field for transformers application. *Industrial Crops and Products*, *89*, 250-256.

Thien, Y.V., Azis, N., Jasni, J., Ab-Kadir, M.Z.A., Yunus, R., Ishak, M.T., Yaakub, M.Z. (2016). Evaluation on the lightning breakdown voltages of palm oil and coconut oil under non-uniform field at small gap distances. *Journal of Electrical Engineering and Technology*, *11*(1), 184-191.

Warmi, Y., & Michishita, K. (2015). A *study on lightning outages on the 150kV transmission line of Payakumbuh – Koto Panjang in West Sumatra in Indonesia*. In 19th International Symposium on High Voltage Engineering, pp. 23–28.

Zhao, X., Xie, Y., He, H., He, J., Chen, X., & Cai, H. (2013). Lightning performance assessment of 500kV transmission lines in Southern China. *IEEE PES Power and Energy Society*, 1-5.

Zulkifli Burhanuddin, Chandima Gomes, Mohd Zainal Abidin Ab Kadir, & Norhafiz Aziz. (2016). *Characteristics of fulgurite-like structures under HV conditions*: *Effects on electrical earthing system*. International Conference on Lightning Protection (ICLP), Estoril, Portugal.

BIOGRAPHY

Mohd Zainal Abidin Ab Kadir received his B.Eng. degree in Electrical and Electronic Engineering from Universiti Putra Malaysia and Ph.D. degree in High Voltage Engineering from the University of Manchester, U.K in 2001 and 2006, respectively.

Currently, he is the Deputy Dean (Research & Innovation) and Professor at the Faculty of Engineering, Universiti Putra Malaysia, Selangor Malaysia. He is also the Founding Director at the Centre for Electromagnetic and Lightning Protection Research (CELP), Universiti Putra Malaysia. Professor Zainal holds several other roles in UPM such as Cluster Head for Applied Sciences and Engineering, Committee for Knowledge Management and Research Planning and Committee for Putra Global (PG) 200.

Professor Zainal is a Professional Engineer (PEng) and a Chartered Engineer (CEng) and currently is the Chairman of the National Mirror Committee of IEC TC 81 (Lightning Protection), Local Convener of MNC-CIGRE C4 on System Technical Performance, Immediate Past Chair of IEEE Power & Energy Society Malaysia, Working Group Member of IEEE PES Lightning Performance on Overhead Lines, CIGRE C4.23 on Guide to Procedures for Estimating the Lightning Performance of Transmission Lines and CIGRE C4.39 on Effectiveness of Line Surge Arresters for Lightning Protection of Overhead Transmission Lines. He is also an Advisory Board Member of the National Lightning Safety Institute (NLSI) USA, Research Advisor for the African Centre for Lightning and Electromagnetic (ACLE) and Advisor to many other government agencies such as SEDA and Energy Commission of Malaysia. He is a member of IET, IEM, CIGRE and a Senior Member of IEEE.

To date he has authored and co-authored over 270 technical papers comprising of high impact journals and conference proceedings. He has supervised and co-supervised 11 PhD and 33 MSc students and currently 24 PhD and 12 MSc are on their way. His research interests include high voltage engineering, lightning protection, electromagnetic compatibility and power system transients. He is also the recipient of the Vice Chancellor Fellowship Award (Young Scientist) 2011, Young Scientist Network (YSN-ASM) 2012, Top Research Scientist Malaysia (TRSM) 2014, Anugerah Tokoh Jasa Gemilang 2015 (contributions to the school's development activities), Tokoh Anak Muda Kelantan (Akademik) 2015 and the nominee for 2015 APEC Science Prize for Innovation, Research and Education (ASPIRE Prize). He is also an IEEE Power & Energy Society (PES) Distinguished Lecturer (DL) in the field of lightning and high voltage engineering. This is a prestigious recognition to the expert who is a well-known engineer and has been working in the selected area for long time. This recognition provides the mobility to the DL to present topics of current interest worldwide and is fully sponsored by the IEEE.

Apart from contributing to the national and international standard development on lightning protection and high voltage engineering, among other his notable contributions to the National and International is to assist the Energy Commission of Malaysia issued a circular relating to lightning protection and to produce a lightning protection handbook as a reference for the engineers, consultants and other organisations within and outside the country. This circular prohibits the use of unsafe lightning protection systems in Malaysia and often referred to as an example to follow by the international lightning protection community. As for the societal contribution, he has shared the knowledge and expertise in the field of lightning protection and safety through his write-up in printed media and his appearances on the national radio and television. For the past several years, he also actively involved in many activities organised by Academy of Sciences Malaysia (ASM) through the Young Scientist Network, for which he is a member of International Networking Group, such as National Science Challenge (NSC) 2013 and motivational talks to school and universities' graduates.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful, the owner of this world and hereafter. May Allah bestow peace and happiness on Prophet Mohammed and his family. All praises are due to Him the Almighty, who grants me with health, courage and patience as a father, husband, son, lecturer and leader, as well as for bringing me to this stage of my life.

I am extremely grateful to Universiti Putra Malaysia for giving me the opportunity to extend and expand my career in my field of interest. It is such a wonderful feeling to contribute back to the place where I was raised academically.

I am also greatly indebted to all members of my research team – Prof. Chandima, Dr. Jasronita, Dr. Norhafiz, Dr. Fatin, Dr. Mahdi, Dr. Maryam, Muzammil and Najib who have been the backbone of our Centre for Electromagnetic and Lightning Protection Research (CELP), which is now blossoming and regarded as the world leader in Lightning Safety. I strongly believe and have a vision that CELP will further expand its 'power' and play a bigger role in lightning- and high voltage-related research at the international level.

My sincere appreciation goes to all 'CELPians' – too many to mention. They are very special to me and we are such a big family. I am always grateful to have such a good friends and colleagues, especially those in Electrical and Electronic Engineering Department.

My special thanks to my technical groups for which I am engaging with, locally and internationally – IEEE PES, ICLP, ACLEnet, NLSI, JKR, SIRIM, Energy Commission, SEDA, Malaysian High Voltage Network (MyHVnet), TC 81, WG 2, MoE and many more. This special thanks also goes to my international colleagues, collaborators, mentors and friends – Emerita Prof Mary Ann Cooper (Illinois University @ Chicago), Prof Farhad Rachidi (EPFL, Swiss), Prof Vernon Cooray (Uppsala University, Sweden), Prof Vlad Rakov (Florida University, USA), Prof Ian Jandrell (Wits University, South Africa), Prof Francesco Roman (National University of Colombia), Dr Chris Andrew (Australia), Dr Siew (Strathclyde University, UK), Dr Cotton and Dr Wang (both from the University of Manchester, UK), amongst many others.

My parents who have been my forever inspiration for their support, courage and love. My family members who are always providing me support and encouragement. Last but not least, I am truly grateful and blessed with such a wonderful wife and children who are so loving and understanding. This journey which are full of sweat, blood and tear are indeed our meaningful journey and whatever the success are belong to us.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

11. Prof. Dr. Abdul Salam Abdullah
    Natural Toxicants Affecting Animal Health and Production
    29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
    Pest Control: A Challenge in Applied Ecology
    9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
    Managing Challenges in Fisheries Development through Science and Technology
    23 July 1994

14. Prof. Dr. Hj. Amat Juhari Moain
    Sejarah Keagungan Bahasa Melayu
    6 August 1994

15. Prof. Dr. Law Ah Theem
    Oil Pollution in the Malaysian Seas
    24 September 1994

16. Prof. Dr. Md. Nordin Hj. Lajis
    Fine Chemicals from Biological Resources: The Wealth from Nature
    21 January 1995

17. Prof. Dr. Sheikh Omar Abdul Rahman
    Health, Disease and Death in Creatures Great and Small
    25 February 1995

18. Prof. Dr. Mohamed Shariff Mohamed Din
Fish Health: An Odyssey through the Asia - Pacific Region
25 March 1995

19. Prof. Dr. Tengku Azmi Tengku Ibrahim
Chromosome Distribution and Production Performance of Water Buffaloes
6 May 1995

20. Prof. Dr. Abdul Hamid Mahmood
Bahasa Melayu sebagai Bahasa Ilmu-Cabaran dan Harapan
10 June 1995

21. Prof. Dr. Rahim Md. Sail
Extension Education for Industrialising Malaysia: Trends, Priorities and Emerging Issues
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22. Prof. Dr. Nik Muhammad Nik Abd. Majid
The Diminishing Tropical Rain Forest: Causes, Symptoms and Cure
19 August 1995

23. Prof. Dr. Ang Kok Jee
The Evolution of an Environmentally Friendly Hatchery Technology for Udang Galah, the King of Freshwater Prawns and a Glimpse into the Future of Aquaculture in the 21st Century
14 October 1995

24. Prof. Dr. Sharifuddin Haji Abdul Hamid
Management of Highly Weathered Acid Soils for Sustainable Crop Production
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Fish Processing and Preservation: Recent Advances and Future Directions
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26. Prof. Dr. Rosli Mohamad
Pesticide Usage: Concern and Options
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27. Prof. Dr. Mohamed Ismail Abdul Karim
Microbial Fermentation and Utilization of Agricultural Bioresources and Wastes in Malaysia
2 March 1996

28. Prof. Dr. Wan Sulaiman Wan Harun
Soil Physics: From Glass Beads to Precision Agriculture
16 March 1996

29. Prof. Dr. Abdul Aziz Abdul Rahman
Sustained Growth and Sustainable Development: Is there a Trade-Off 1 or Malaysia
13 April 1996

30. Prof. Dr. Chew Tek Ann
Sharecropping in Perfectly Competitive Markets: A Contradiction in Terms
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Back to the Future with the Sun
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Enzyme Technology: The Basis for Biotechnological Development
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The Fascinating Numbers
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34. Prof. Dr. Ho Yin Wan
Fungi: Friends or Foes
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Genetic Diversity of Some Southeast Asian Animals: Of Buffaloes and Goats and Fishes Too
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Will Rural Sociology Remain Relevant in the 21st Century?
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Food and Its Healing Power
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Biological Control of Plant Pathogens: Harnessing the Richness of Microbial Diversity
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The Endomycorrhiza: A Futile Investment?
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Molecular Plant Virology: The Way Forward
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Managing Change in the Agriculture Sector: The Need for Innovative Educational Initiatives
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Analisis Pemasaran Pertanian di Malaysia: Keperluan Agenda Pembaharuan
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